SPECIAL REPORT

OF THE

RHODE ISLAND
STATE BOARD OF HEALTH

ON THE

Cause, Prevalence and Effect of

OFFENSIVE ODORS

IN

PROVIDENCE, CRANSTON, EAST PROVIDENCE
AND WARWICK DURING 1921


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INVESTIGATION OF OFFENSIVE ODORS

PRESENTED TO THE GENERAL ASSEMBLY
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Special Report of the State Board of Health on Investigation of Offensive Odors.

To the General Assembly:

As directed by Resolution No. 35, passed by your honorable body at the January 1921 Session, the State Board of Health has caused an investigation to be made by its Sanitary Engineer of offensive odors, caused by trades, occupations and employments in the cities of Providence and Cranston, and in the towns of East Providence and Warwick, and present for your consideration the following report.

REPORT.

On October 15, 1920, a resolution was passed by the City Council of the City of Cranston officially calling to the attention of the State Board of Health the fact that for a considerable time foul and disagreeable odors, injurious to the health and well being of the community, had been prevalent in the Edgewood and Pawtuxet sections, which odors were reputed to come from certain oil plants located outside the jurisdiction of the City of Cranston, and requesting that the State Board of Health take such action as lay within its power to abate the nuisance.

On November 17, 1920, written complaints were also received by the Board from persons residing in the East Side of Providence, stating that odors were prevalent in that section which were offensive and detrimental to health.

At the regular meeting of the Board on November 18,1920, these complaints were referred to our Sanitary Engineer for investigation, and at the regular meeting on December 8, 1920, our Sanitary Engineer reported in part as follows:

"It seems probable that the odors noticeable in the Edgewood and Pawtuxet sections of Cranston and the Washington Park section of Providence emanate from the refining plant of the Texas Company located at Fields Point. The odors complained of on the East Side of the City of Providence may come from this plant. . . . As there are other oil companies operating within a radius of five miles of the affected sections, and as there are one or more firms engaged in the manufacture of products from tar or oil wastes within the same area, it is quite possible that one or another of these plants may be responsible for the nuisance at certain times, or in certain sections. . . . The odors may be described as a mixture of hot partly burned oil mingled with burning rubber, and a sweetish smell somewhat like purified naptha. . . . These odors are certainly very disagreeable, and on certain persons, depression, nausea, and a feeling of suffocation are produced by them. . . . In certain cases I understand that physicians have been called to treat persons who have been affected by these odors. . . . Before any action can be taken to suppress or control the nuisance it will be necessary to establish definitely which plant or plants are the offenders. . . . Under the General Laws, the State Board of Health has authority to make investigations, but no authority to prevent nuisances. . . . The problem is a large one involving a considerable amount of detailed investigation which will require a number of months. . . . A complete investigation to establish what plants are responsible for the nuisance will require a number of trained observers to establish the exact areas affected and the intensity of odors therein at times when odors are noticeable. . . . The reports of volunteer observers are usually too indefinite to be of great value, although they may be useful to supplement the data collected by trained men."

In its estimates of funds needed for work during 1921 the Board requested that $1,500 be appropriated for a more complete investigation of this problem. At the 1921 Session, a Resolution was introduced into the General Assembly by Mr. Sharp of Providence appropriating $1,500 for this purpose. This Resolution was passed, with an appropriation of $1,000.

Early in March, 1921, a petition signed by sixty-five residents of the East Side section of Providence was sent to the Governor asking for relief from offensive odors, a copy of this petition being also forwarded to the State Board of Health.

On March 15 a communication was received from the Commissioner of Public Health of Massachusetts, enclosing a copy of complaints made by residents of Seekonk, Mass., relative to offensive odors originating from the Standard Oil Company refinery in East Providence, and requesting the State Board of Health of Rhode Island to investigate and take such action as lay within its powers.

As our investigation was originally planned, we expected to be able to obtain within a few months reasonably complete information relating to the frequency of odors, the sources from which odors were coming, the territory and population affected from each source and the effect of these odors upon the health of persons residing in these various localities. Before the investigation had proceeded very far, it became evident that the problem was of much greater magnitude and far more complicated than we had anticipated and that a complete investigation could not be made of all possible sources of odor within the limits of the funds appropriated for the purpose. It has been necessary, therefore, to limit the investigation to certain major points and to study intensively the major sources from which offensive odors were coming, leaving a more complete study of other points to the future.

In accordance with the provisions of the Resolution ordering this investigation, reports of our results have been made to the Attorney General from time to time for his information.

As it became more and more apparent that certain phases of the problem, particularly those relating to the use of oil as fuel, were subjects involving a broad knowledge of fuel engineering and boiler practice, our Sanitary Engineer was authorized to invite the State Boiler Inspector and the Providence Engineering Society to coöperate in the investigation. The Board wishes at this point to acknowledge the assistance received from these sources. In addition we are indebted to Mr. Ralph W. Eaton, Public Service Engineer of Providence, for information as to the location of oil burning plants.

The methods employed and the results obtained in this investigation are described and discussed in detail in the report of the Sanitary Engineer of the Board, which is appended to and made a part of this report. Certain of the more important findings of that report may be briefly summarized as follows:

From our own observations, it is evident that certain parts of Providence, Cranston, East Providence, Barrington and Warwick, and also a portion of the town of Seekonk in Massachusetts, are being very badly affected by odors which originate in Providence or East Providence.

The major odors about which complaint is made are those resulting from the distillation and refining of petroleum and from the use of petoleum oil as fuel. At Fields Point in Providence the Texas Company operate a plant for the distillation of crude oil and the manufacture of asphalt. At Vanity Fair in East Providence, the Standard Oil Company operate a complete oil distilling and refining plant which is one of the largest plants of its kind in New England. The odors due to waste gases and fumes from these processes are offensive and when discharged in any considerable amounts into the air may travel to a distance of three to four miles. As both of these plants are located within easy odor travel distance of large and closely settled residential districts, conditions are favorable for the creation of an extensive nuisance.

Another prolific source of odors arises from the incomplete combustion of fuel oil in power and heating plants. These odors are essentially the same as those arising from petroleum distillation and refining plants and have the same characteristics. Certain sections of Providence and East Providence are quite seriously affected with odors of this kind at times.

Other sources of offensive odors about which complaint has been made are the Tar Products Corporation, and the Industrial Chemical and Color Company, located near the Seekonk River in East Providence, and certain slaughter houses and rendering plants located in Pawtucket. The Tar Products Corporation is engaged in the distillation and recovery of various commercial products from tar during which fumes or odors are emitted at times which are very penetrating and disagreeable. The fumes given off from the plant of the Industrial Chemical

Map of Providence showing Location of Odor Complaints (*black spots*), Oil Burning Plants (*black crosses*) and Principal Sources of Odor. (*Stars.*)

Company are acid in character and are irritating rather than malodorous.

During the period from June to October inclusive, nightly observations were made by employees of the Board in those sections which were alleged to be affected by odors. The reports of these observers when combined with reports of volunteer observers and complainants furnish evidence of the frequency of the occurrence of offensive odors and of the sources from which they originate.

In the Providence, Cranston, Warwick district, odors affecting a greater or less territory were noted by our observers on 48 different nights. On 44 of these nights offensive odors were traced to the Texas Company plant. On 4 nights also offensive odors of similar character were recorded as coming across the river, which probably originated at the Standard Oil Company plant. On 6 different nights a strong odor of illuminating gas affecting a considerable territory was traced to the Providence Gas Company plant. On 2 nights a strong ammoniacal odor was reported from the Clapp Ammonia Co. plant.

In the East Providence district odors were observed and traced to the refinery of the Standard Oil Company on 40 different nights, and volunteer observers have reported the occurrence of offensive odors from this source on 10 other dates. Owing to the general prevalence of light westerly and southerly winds, that part of Seekonk known as Luther's Corners has been very badly affected by the odors from the Standard Oil Company plant. On 9 occasions odors were noted in East Providence which, from their character and the direction of the wind at the time, must be attributed to the Texas Company plant at Fields Point. Odors coming from the Tar Products Company were also recorded in this district on 7 nights, and odors from miscellaneous sources in Providence were noted on 5 nights.

In the East Side district of Providence the presence of odors in one or another section were reported by our observers on 67 nights, and volunteer observers reported odors on 45 other dates, making a total of 112 different days during this period when one or another part of this district was affected by odors.

Unlike the other districts, most of the odors affecting the East Side district originate from incomplete combustion at power plants or other sources where oil is used for fuel. Odors of this character affecting the East Side section were reported as originating at the power plant of the Narragansett Electric Company on 34 different dates, and at power plants located at Phillipsdale in East Providence on 10 different dates.

Offensive odors in the East Side section bordering on the Seekonk River were also reported as coming from the distributing station of the Standard Oil Company at the end of Red Bridge in East Providence on 6 nights, and from the Tar Products Corporation on 20 dates. Odors in the northerly part of the East Side on 6 different dates are attributed to slaughter houses or rendering establishments located in Pawtucket.

In order to ascertain in what degree these various odors were affecting the health, we have endeavored to ascertain from personal interviews with a large number of complainants in just what manner different persons were affected. It was manifestly impossible to interview all of the persons in the odor infected districts or to determine by a house to house canvass just what proportion of the population was being affected. Definite information has been obtained, however, of 96 persons who appear to have been more of less seriously affected by these odors.

The most common symptoms complained of were irritation of the throat, choking sensation, suffocation, nausea, headache, dizziness, and malaise.

In order to supplement the results obtained in this part of the investigation a letter of inquiry was sent to all physicians in the State requesting reports on all cases under their care which resulted from or were being affected by odors of this character. In replies to this inquiry 10 physicians reported that they had treated 32 patients whose illness could properly be attributed to odors or fumes of this nature. In a majority of instances these cases of illness were reported to have lasted not more than one or two days. One physician, however, reported a case of headache and cyanosis, the symptoms of which persisted for at least two weeks, and another physician

reported a case of persistent headache, nausea and loss of appetite which had a duration of some eight months. Nine physicians also reported 15 cases of other diseases in which the symptoms of the patient had been very much aggravated by odors of this character. These cases included pulmonary tuberculosis, pharyngitis, laryngitis, asthma, anaemia, cardiac trouble, and nervous diseases.

From this evidence we must conclude that these odors are not only affecting the comfort of the people residing in these various districts, but that in a certain measure they are also affecting the health of many of these people.

The question of odors as a public health matter was admirably summed up by Prof. George C. Whipple in an address before the American Society of Civil Engineers in November, from which the following quotations are taken:

"Odors that are offensive to human beings and travel over wide areas are public nuisances and come within the scope of police power, a power exercised in this case by State or local boards of health. . . . In a physiological sense, meaning a condition of the body in which it operates normally, the effect of odors on health is ordinarily slight . . . yet intense odors may cause reflex actions of the digestive, muscular, and secretory systems. . . . The irritants may cause smarting sensations and respiratory discomfort and probably are more closely related to health than true odors. Offensive odors may cause people to refrain from breathing deeply, may cause loss of sleep, restlessness, loss of appetite, and general malaise. These are certainly matters which appertain to health, and to some people they are of serious import.

"If the word, health, is extended to include the psychological as well as the physiological, if it included human comforts as well as bodily functions, then odors do have an important influence on health. . . . Human beings continue to insist that health and comfort be kept together and not separated artificially. . . . The health and comfort of people is an expression which not only has a great human urge back of it, but which has been found to stand the test of the courts."

So far we have been able to ascertain there has not yet been any appreciable injury to buildings, animal or vegetation by

the large amounts of gases discharged into the air from the various oil refining and oil burning plants, although no attempt was made to investigate this point thoroughly. Damage to property may result from the fact that areas affected by odors or fumes become less desirable for residential purposes. This is a point which warrants serious consideration. The large areas in Providence, Cranston, East Providence and Warwick, which are now badly affected by odors, are almost entirely given over to homes of the better class with a high tax valuation. A serious depreciation in property values would result not only in considerable financial loss to the individual property owners, but would also seriously affect the revenues which these cities and towns derive from taxation.

In the opinion of the Board one of the great problems suggested by the investigation is what affect on the public health is likely to be produced by the change now taking place from coal to oil as fuel for power and heating purposes.

In an industrial community such as Providence, however, large numbers of oil burning plants may be concentrated within a relatively small area and the atmosphere under such conditions cannot help but be impregnated with amounts of these gases which may readily be detrimental to the health as well as the comfort of persons breathing them.

This is a problem which demands full and complete investigation in order that all the effects of this change in character of fuel may be established and reasonable and proper methods for preventing serious injury to health and property may be devised.

RECOMMENDATIONS.

In conclusion we would recommend:

1. That the Board be authorized to continue the investigation of the source and effect of offensive odors, especially in connection with the burning of high sulphur fuel oils, and of other odor producing industries and processes.

2. That the special powers granted to the Board by Resolution No. 35 be continued during the time necessary for this investigation.

3. That a special appropriation of $5,000 or so much thereof as may be necessary be made for the purpose of this investigation.

4. That the territorial limits specified in Resolution No. 35 be removed and the Board be empowered to extend the investigation to such other cities and towns within the State as may become necessary or advisable for the purpose of obtaining full and complete information as to the cause and effect of offensive odors.

5. That the Board be granted statutory authority to investigate complaints of nuisances caused by offensive odors from trades, industries, processes, to advise with manufacturers, and other persons engaged in such trades or industries, or employing such processes, as to the best methods for the prevention or control of offensive odors, and authority to prohibit or regulate such trades, industries or processes as may be, or may become, a public nuisance, or a detriment to the health and comfort of the people.

B. U. RICHARDS, M. D.,
Secretary.

REPORT ON AN INVESTIGATION OF THE CAUSE, PREVALENCE AND EFFECT OF OFFENSIVE ODORS, IN PROVIDENCE, CRANSTON, EAST PROVIDENCE AND WARWICK DURING 1921.

By Stephen DeM. Gage,

Chemist and Sanitary Engineer of the Board.

Rhode Island State Board of Health:

Gentlemen:

I present herewith a report of the Investigation of Offensive Odors made by the Division of Chemistry and Sanitary Engineering of the Board as ordered at the last session of the General Assembly in Resolution No. 35.

In a report on a preliminary investigation of this subject December, 1920, I stated that we had reasonable evidence to believe that the odors about which complaint was made originated from plants operated by the Standard Oil Company and by the Texas Company for the distillation and refining of petroleum, and for the purpose of a full investigation of the cause and effect of odors from these sources I estimated that at least fifteen hundred dollars would be needed. Since it has developed that the problem was much more complicated and the odor nuisance much more extensive than we had anticipated, the sum of one thousand dollars appropriated has been entirely too small for the purpose, and our investigation has therefore been necessarily limited in scope and far from complete in many particulars.

Our investigation has been conducted along two main lines; first to determine the main sources of odor, the frequency with which odors were emanating from these sources and extent of the nuisance caused by each; second to determine what effect

these odors may have on the health of persons who are forced to breathe them.

In order to determine the sources and frequency of odor, the territory affected has been divided into three districts in each of which an employee of the Board has made observations of the occurrence of odor each night during a period of one hour at the time when odor was most likely to be prevalent. Whenever possible these special observers have also traced any odors noted to their point of origin. In addition blank forms with return envelopes were supplied to complainants in each of these districts and they were requested to report odors noticeable at their homes whenever they occurred. Surveys were also made on a number of occasions when the odor nuisance was especially marked to determine the extent of the area effected. Special observations have also been made on certain oil burning plants which had been found to be sources of odor at times, to ascertain at what particular time of day or night offensive fumes might be given off.

In our study of the public health phase of the question a large number of complainants have been interviewed by a qualified physician to ascertain what effect was being produced by odors upon the health of various persons, and every physician in the State has been requested to furnish us with any information which he might have on the subject.

During the progress of the investigation I have personally made a number of visits to the plants of the Texas Company and the Standard Oil Company for the purpose of studying the various processes of distillation and refining as carried on at those places. At each of these visits every facility has been afforded us to obtain the desired information and the management has evinced a willingness to coöperate with us in locating the sources of odor and to take any reasonable means of eliminating the nuisance which we might be able to suggest. Through the courtesy of Mr. Buerger, Manager, and Mr. Weston, Consulting Sanitary Engineer, I have also been permitted to make a number of visits to the plant of the New England Oil Company at Fall River to see the methods employed in a similar investigation and to inspect various devices being installed for the prevention and control of odors. Throughout the investigation

also we have been in close touch with similar investigations being made by the Massachusetts Department of Health, and on a number of these inspection trips I have been accompanied by the Engineer in charge of these investigations and have had the benefit of his knowledge of the conditions which prevail at other places.

As our studies progressed, it became more and more evident that in the investigation and solution of those phases of our problem which related to the use of petroleum as fuel a much broader knowledge of fuel engineering and boiler practice than that possessed by the writer were desirable. In September, therefore, with the approval of the Board, the State Boiler Inspector, and the Providence Engineering Society were invited to coöperate with us by such advice and assistance as they might be in a position to furnish. In response to this request Mr. Farmer, the State Boiler Inspector, has collected for us much valuable information and has advised as to its importance and application to our particular needs. The Providence Engineering Society has also appointed a special committee which has given much time to a consideration of the oil burning situation. A preliminary report of this committee appended to this report contains many pertinent suggestions for further study of the problem.

Before proceeding with a discussion of the results which we have obtained the writer wishes to express his obligation to the various persons mentioned above and to Dr. Charles V. Chapin, Superintendent of Health of Providence, for advice and assistance in laying out the investigation, to Mr. Robert W. Eaton, Public Service Engineer of Providence, for assistance in obtaining a list of the oil burning plants in the city, and to the volunteer observers who have assisted by reporting the occurrence of odors from time to time. Mention should also be made of the helpful spirit displayed by our regular observers in tracing down odors at times when they were not on duty, and of the assistance rendered by Mr. Griffin of our staff who has spent a number of nights in the field checking up the work of various observers and has also compiled and verified the reports and other data obtained from different sources.

Opportunities for Odor from Handling, Distilling and Refining Petroleum.

Before entering into a detailed consideration of the results of our investigation it may be advisable to describe briefly the petroleum industry as it exists in Providence and vicinity today particularly in relation to the various methods of handling, storing, distilling and refining as possible sources of odor.

There are six large plants for receiving, storing and distributing petroluem and petroleum distillates on the shores of Upper Narragansett Bay and the Providence and Seekonk Rivers. Four of these, the Standard Oil Company, the Gulf Refining Company, the Mexican Petroleum Corporation and the Tide Water Oil Corporation are located in East Providence, and one, the Texas Company, is located at Fields Point in the city of Providence. The Standard Oil Company operates two plants, a large one at Vanity Fair and a smaller one at Red Bridge. At these various stations large quantities of crude petroleum, fuel oil, gasoline, and other petroleum products are stored in tanks and from these tanks are pumped to tankcars, or wagons for distribution as needed. Practically all of this oil is received by water in tank steamers from which it is pumped directly to the storage tanks.

At these various plants a large amount of fuel is required to supply power for pumping and to maintain the heavier bodied oils at a temperature at which they will be fluid, and for this purpose oil burning steam plants are maintained. The production of offensive odors from oil burning plants is discussed elsewhere, but it may not be out of place to state here that a certain proportion of the odors originating from two of these plants may have resulted from incomplete combustion in their steam plants. All or nearly all of the tank steamers serving these various stations also use oil fuel and may contribute to the odor nuisance at times.

During storage of these products, especially those which are heated, there is a constant escape of gaseous or other volatile matters, and for this reason there is always some odor around the tank field where oil is stored in quantity. In open tanks this evaporation loss may be as much as one percent and even

with closed tanks such as are used in Rhode Isalnd there is some loss of this kind. At some places the storage tanks are connected with a vacuum system by which escaping gases, etc., are collected and conducted to the fire-box of the boilers. Under this arrangement not only is the possibility of an odor nuisance from this source prevented, but valuable fuel is utilized instead of wasted. At all of the storage plants in the vicinity of Providence the tanks are vented directly into the air and no attempt is made to conserve these waste gases. During the filling of the tanks or of tank cars, etc., such gases are forced out into the air in considerable quantities and a local odor nuisance may be created thereby. The complaints as to odors from the Standard Oil Company Red Bridge Station may have been caused in some such manner.

At Fields Point the Texas Company operate a plant for the manufacture of asphalt. In this process either crude petroleum, or petroleum from which the lighter naphtha distillate has previously been removed, is subjected to distillation until only the heavy bodied asphalt or pitch remains. This residue is then run out into moulds, and when cold is broken up and sold as paving material or for use in the manufacture of roofing papers, etc. The hot asphalt has a distinct penetrating odor which may travel some distance under certain weather conditions. At the Texas Company no refining is carried on, the intermediate oils obtained by distillation being shipped in tank steamers to other refineries for further treatment.

The processes conducted at the Standard Oil Company works at Vanity Fair include both low pressure and high pressure distillation and also the refining of petroleum products. In the low pressure stills crude petroleum is separated into various grades by fractional distillation. In the high pressure or cracking process, petroleum from which the low boiling fractions have been removed is subjected to high temperature and pressure in order to crack or break down the higher boiling hydrocarbons into lower boiling products such as gasoline and kerosene. In the refining process the gasoline, kerosene, or other distillation product is agitated with concentrated sulphuric acid to remove the unsaturated hydrocarbons, sulphur compounds and other impurities. The mixture of acid and oil

is then pumped into tanks where the acid sludge separates from the oil by gravity. The supernatant oil is then washed with water to remove excess acid, separated by gravity, agitated with caustic soda and a small amount of litharge to neutralize the remaining acid and remove any remaining sulphur compounds, and again washed with water. After a final sedimentation to remove water and settleable impurities, the refined product is pumped to storage tanks for distribution. When carried out in open tanks, as is the case at some of the older plants, this refining process is the source of strongly acid fumes which are very offensive. At the Standard Oil plant the entire process is conducted in closed tanks and the only opportunity for odors to escape is through leaks in the various valves and connections.

The acid sludge from the refining process is a heavy black asphaltic liquid containing in addition to the acid, the unsaturated hydrocarbons, sulphur, and nitrogen compounds and other impurities removed from the refined oil. This sludge is agitated with water and the dilute acid and sludge oil separated by gravity. The weak acid is then concentrated by evaporation to be used over again. At many refineries this acid recovery process is carried out in open pans and the steam from the evaporation, mixed with volatile products from the traces of sludge oil carried over with the acid gives rise to very offensive odors. At the Standard Oil Works a new acid recovery plant has recently been put into operation in which all the various steps are carried out in sealed vessels, the steam from the evaporation being condensed and run off into the sewers, and the non-condensible gases from the process being conducted to a special furnace where they are burned. The sludge oil produced at this plant is mixed with the fuel oil and burned under the boilers. As practically all of the impurities removed in the refining process are concentrated in the sludge oil, unless complete combustion is obtained when this mixture with fuel oil is burned the stack gases are likely to be extremely offensive.

In the distillation process a large amount of water is required for the condensers, and through leaks in the condenser connections a certain amount of the distillate finds its way into this condenser water. At the Standard Oil Plant there was a short-

age of cooling water during the past summer, and the warm water from the condensers, after being passed through tanks to separate the oil, was cooled for re-use by being sprayed into the air through fine jet nozzles. At times considerable odor was given off from this cooling plant which, while it did not appear to travel to any considerable distance, was distinctly noticeable on the road running by the easterly side of the works.

During the distillation process a certain proportion of the oil is converted into fixed gases which cannot be condensed. These gases have more or less odor depending upon the character of the oil being distilled. In the cracking process which is employed by the Standard Oil Company not only is the yield of gasoline very much increased by the breaking down of the higher boiling hydrocarbons, but a considerably increased amount of fixed gas is also formed. The products of cracking, both liquids and gases, always have a strong cracked or burnt odor, and are particularly offensive when sulphur bearing oils are being treated. These fixed gases have a high fuel value and the usual practice at distilling plants is to pipe them back to the fire boxes under the stills and burn them. The temperature of stills must be very carefully regulated and as the production of fixed gas is greatest at the beginning of distillation when the least amount of heat is needed, the large excess of gas formed is likely to pass through the fires without being completely burned. It is difficult also to keep the stills, condensers, and other piping absolutely gas tight, and unless this is done considerable gas may find its way into the air through leaks. At one distilling plant (not in Rhode Island) the excess gas so greatly exceeded the fuel demand at times that this gas was conducted to a separate furnace and burned to prevent its becoming a nuisance.

At many refineries the gas is collected by a vacuum system by which its escape through leaks in the stills and condensers is largely prevented. The fixtures at more modern plants also include a gas holder to store the excess gas produced at certain stages of the distillation for use at other times. At the Standard Oil Company the equipment includes a vacuum system, and a gas holder was constructed during the past summer. When these are put into use they should help to reduce odors from

that source. About two years ago apparatus for washing the still gases with water before they were conducted to the fire-box was installed at the Texas Company plant. The use of this apparatus, however, failed to appreciably reduce the odors arising from this source. Early in December the method of handling these gases at the Texas Company was changed and instead of being burned under the stills, they are now carried to the fire-box under the boilers where a much larger and hotter fire is maintained. As the distilling plant at the Texas Company is operated only intermittently during the winter, the effectiveness of this change has not yet been demonstrated.

During the distillation process carbon is deposited on the shell of the still as a scale and this scale has to be removed at intervals by manual labor. In the high pressure or cracking process the demands of safety require that the stills be cleaned and inspected after each run or about every three days, although the low pressure stills may be used a number of weeks before cleaning. As the gases remaining in the still after drawing off the oil residue are highly poisonous, these have to be removed by steaming out before the workmen can enter. This steaming out process has been the source of odor complaints in a number of instances. At both of the Rhode Island plants the exhaust steam from the stills in such cases is conducted to a steam trap where it is supposed to be condensed and with the absorbed gases flow off into the sewers.

Character and Intensity of Odors.

Crude petroleum may be described as a compound or mixture of various solid, liquid and gaseous hydrocarbons together with certain impurities. The composition of the petroleum from the different oil fields varies widely as does also the character and amount of impurities which it may contain. Practically all of the petroleum brought into the port of Providence today comes from the Texas and Mexican oil fields and contains sulphur and perhaps nitrogen compounds in greater or less amounts. Most of these sulphur and nitrogenous compounds have very strong disagreeable odors and it is to the liberation of such compounds or their oxidation products into the air during the treatment or

burning of these southern petroleums that the odor nuisance in Providence and vicinity can be largely attributed.

The odors which we have observed as coming from the Texas Company and Standard Oil Company plants and from certain oil burning plants vary considerably in character from time to time, and may also vary as the distance from the source and the consequent dilution with air is increased. These odors are variously described as like rotten eggs, hydrogen sulphide, sulphides, burnt rubber, sweetish burnt rubber, burning garbage, sulphurous, acid, irritating, etc. Near their source when strong they are most likely to resemble rotten eggs or sulphides. At a little distance the same odor may smell something like burning rubber with perhaps a sweetish flavor, while at a somewhat greater distance the rubber constituent disappears and the odor takes on the characteristics of burning sugar or perhaps that of scorching paper. At times these odors may be very irritating to the eyes, nose and throat and at other times they may be merely disagreeable to the smell. At times although no obnoxious odor can be smelled, one is acutely aware of the presence of these products by the irritation of the nose or throat. The reason for these variations in character have not been determined. Probably the odors noted are a mixture of various substances in varying quantities, some of which are more overpowering or have greater carrying properties than others. It is well known that some apparently simple odors change materially in character with the intensity of dilution and that a blend of two or more odors may have entirely different properties from either one alone. This changing character caused some confusion at the beginning of the investigation until we had learned that many of the different smells noted above were usually one and the same except in the matter of intensity.

In our investigation we have taken considerable pains to ensure that odor observations in the various districts should be reasonably comparable. As the acuteness of the olfactory sense varies widely in different people, in selecting observers for this work we have tried to obtain men whose sense of smell was reasonably acute, and to teach these men to record odors of similar intensity in a similar manner by comparing notes with one another. As an additional safeguard the work of

each observer has been checked from time to time by the writer and by Mr. Griffin of our staff.

The scale used for recording odors was the same as that used for reading odors of water, "very faint," "faint," "distinct," "strong," and "very strong." A "very faint" odor would be observed by some persons, but would be unnoticed by the majority. A "faint odor" would be detected by the majority and would be disagreeable to a few. A "distinct" odor is one which would be distinctly noticeable to almost everybody and would be disagreeable to the majority. A "strong" odor is one which would be objectionable to practically everybody. A "very strong" odor would be decidedly objectionable to all except those with a defective sense of smell. Records of odors described in this manner are very useful for comparative purposes, but cannot be readily used as a basis for mathematical expression of odor intensity.

As a matter of convenience and to save space on the record blanks, odors of water are frequently expressed by the numerals 1 to 5 inclusive, a "very faint" odor being recorded by the figure "1" and a "very strong" odor by the figure "5." For lack of a more accurate method these numbers are also sometimes added and divided by the total number of observations to obtain some idea of the average odor intensity. We have, however, no real basis for assuming that a "faint" or "number 2" odor is twice as intense, or that a "distinct" odor is three times as strong as a "very faint" or "number 1" odor. As a matter of fact, judging from the investigations of odor intensity by Allinson & Katz and others, the ratio between the different amounts of volatile substances and gases required to produce different odor intensities in an olfactory sense may vary through wide limits.

Accurate methods have already been worked out and special apparatus has been devised by which extremely small amounts of certain of the constituents of the odors from petroleum distillation and oil burning plants can be detected and measured in air. While we were well aware that these methods and apparatus were available and that they were being used to obtain accurate odor records in a similar investigation in a neighboring state, we were unable to use them in our own in-

vestigation, since to buy the apparatus and have it rebuilt to conform to the very peculiar electric current conditions of Providence, would have consumed nearly one-half of our appropriation. It was necessary, therefore, to make the best use we could of the olfactory senses of our observers, leaving more accurate measurements of pollution of the air to a time when more adequate funds should be available.

Prevalence of Odors in Different Districts.

Our information as to the frequency of odors in the various parts of the odor affected districts has been derived from two sources; first, from observations made each night by regular employees of the board; and second, from signed reports sent in from time to time by volunteer observers living in those districts. Our regular employees whenever possible have traced any odors which they have noted to the source from which they originated, and from their reports we are able to determine not only the frequency of odor during the middle night hours, but also to determine the frequency with which odors were being created at certain sources. The reports of volunteer observers furnish a check on the reports of our regular observers and also supply information as to the occurrence of odors at other times when our regular observers were not on duty. As might be expected, reports from volunteers were received at irregular intervals when the visitation of odors was especially marked, and except in one or two instances no attempt was made by these observers to keep a complete record of the occurrence or non-occurrence of odor. In many of these reports it was stated that odors came from certain specified sources, although as a rule the volunteer observer did not trace out the source of odor. In a considerable number of cases, however, the probable source of odor reported by volunteers could be traced by a study of the direction of the wind at the time or by comparison with one another and with reports of our regular employees. These records, therefore, while individually of relatively small importance, supply corroborative evidence of the frequency of odors which is of considerable statistical value.

Night observations were made in the Providence, Cranston, Warwick district on 148 nights. On 64 of these nights it was reported that the wind was off shore and that the district was free from odors. On the remaining 84 nights odors were noted by our observer on 48 different nights. On 44 of these nights offensive odors affecting a greater or less territory were traced to the Texas Company plant. On 4 nights also offensive odors of similar character were recorded as coming across the river which probably originated at the Standard Oil Company plant.

On 5 nights also a strong odor of illuminating gas from the plant of the Providence Gas Company was reported in this district and on two nights a strong ammoniacal odor was reported coming from the plant of the Clapp Ammonia Company. In addition volunteer observers have reported offensive odors on nine other dates at times when our regular observer was not on duty. The correlated records from the two sources therefore, show that one part or another of this district was affected by offensive odors on 57 different dates during the five months from June to October inclusive.

Night observations were made by our regular observer in the East Providence district on 121 different nights and the presence of offensive odors was reported on 65 nights. On 40 of these nights odors in one or another part of this district were traced to the refinery of the Standard Oil Company. On seven nights this observer reported odors in his district from the plant of the Tar Products Corporation. Odors were reported as coming across the Providence River into East Providence on nine nights which from their character and the direction of the wind at the time must be attributed to the Texas Co., and on one night a strong odor of illuminating gas was reported as coming across the river, probably from the Providence Gas Company plant. Offensive odors in this district from incomplete combustion of fuel oil are attributed to the Colored Worsted Company on one night and to the Narragansett Electric Lighting Company on two nights. In addition other employees of the board have reported offensive odors in this district at times when our regular night observer was off duty on five dates from oil burning plants at Phillipsdale

and on four dates from the Tar Products Corporation, and volunteer observers have reported odors which undoubtedly can be attributed to the Standard Oil Company refinery on ten other dates. The correlated records from all sources, therefore, show that one part or another of this district was affected by offensive odors on 75 different dates during the period covered by the investigation.

The East Side section of Providence has been not only the most thoroughly "gassed" of any of the districts under observation during the past year but, owing to the multiplicity of sources from which it may be affected, has been the most difficult section in which to trace out and definitely locate these various sources. In a considerable number of instances the odors from two or more sources were blended and as these odors were frequently almost identical in character and were coming in on the wind from outside, the location of their exact source required much study and was often impossible. The district lies within observed travel distance of odors from both the Standard Oil Company refinery in East Providence and the Texas Company plant at Fields Point, and while none of the odors in this section can be definitely attributed to these sources it is quite possible that they may have contributed to the combined nuisance. Within the borders of this district are included a number of oil burning plants, some of which are known to be and others of which may be sources of odor at times. Just outside the district on the south is the large oil burning power plant of the Narragansett Electric Lighting Company backed up at a somewhat greater distance by a considerable number of smaller oil burning power and heating plants. On the opposite side of the Seekonk River and within easy odor travel distance are the Standard Oil Company and the Tide Water Oil Company distributing plants, the Tar Products Corporation plant, the plant of the Industrial Chemical and Color Company, and the oil burning power plants of the Wire Works and the Sayles Finishing Company of Phillipsdale. In addition the northerly part of the East Side is subject to odors from slaughter houses or rendering works located in Pawtucket. In the other districts a change in the direction of the wind might bring relief from odors for a time, but to the

East Side dweller a change of wind afforded only a change of odor.

Observations were made in this district by an employee of the board on 158 nights, and odors were recorded on 67 nights. In addition offensive odors have been reported by other employees of the board or by volunteer observers on 45 additional dates, thus making a total of 112 different days or nights during the period covered by the investigation when a greater or less proportion of this district was infested with offensive odors of one kind or another. These odors were traced to the Narragansett Electric Lighting Company on 34 different dates, to the Colored Worsted Company on 10 dates, and to the Tar Products Corporation on 9 dates. Odors were also either definitely traced or attributed to the oil burning plants at Phillipsdale on 11 dates, to the Standard Oil Company distributing plant on 6 dates, and to the slaughter houses or rendering plant on 6 dates. On 13 dates it was impossible to trace or to definitely locate the source of the odor in this section owing to the absence or variable character of the wind at the time.

The prevalence of odors in the different districts is summarized in the following table:—

Summary of Observations on Prevalence of Odor.

	Providence Cranston Warwick District	Providence East Side District	East Providence District
Number of nights observations were made by regular employees	148	158	121
Number of nights odor reported	48	67	65
Additional dates odors reported by volunteer observers	9	45	10
Total number of different dates odor reported	57	112	75

Frequency of Odors from Different Sources.

The prevalence of odors from various sources has been discussed from the viewpoint of their cumulative effect as noted in different sections of Providence and its suburbs. Odors like the elements are not limited by geographical boundaries and for this reason or because of changes in direction of

the wind odors from certain sources have been recorded in different districts on the same date. In order to present a fair statement of the nuisance created by odors from each source it is necessary also that the frequency of odors be tabulated by sources. The results of such a tabulation show that during the period of about six months covered by the investigation odors were reported as coming from the Texas Company on 52 different days or nights, from the Standard Oil Company refinery on 43 dates, from the Power Plant of the Narragansett Electric Lighting Company on 40 dates, from the Tar Products Corporation and from oil burning power plants at Phillipsdale on 16 dates each, from the Colored Worsted Company on 11 dates, from the Providence Gas Company plant, from the Standard Oil Company distributing plant on the Seekonk River and from slaughter houses or rendering plants in Pawtucket on 6 dates each, and from the Clapp Ammonia Company on 2 dates.

The prevalence of odor in various districts and the frequency of odor reported from different sources is shown in the following table:—

Number of Different Dates Odor Reported from Various Sources.

Source of Odor.	Providence Cranston Warwick District	Providence East Side District	East Providence District	All Districts
Texas Co	44	0	9	52
Standard Oil Co.—Refinery	4	0	40	43
Narragansett Elec. Lighting Co.	*9	34	2	40
Tar Products Corporation	0	9	11	16
Phillipsdale Power Plants	0	11	5	16
Colored Worsted Co	0	10	1	11
Standard Oil Co.—Red Bridge Station	0	6	0	6
Providence Gas Co	5	0	1	6
Slaughter House, etc	0	6	0	6
Clapp Ammonia Co	2	0	0	2

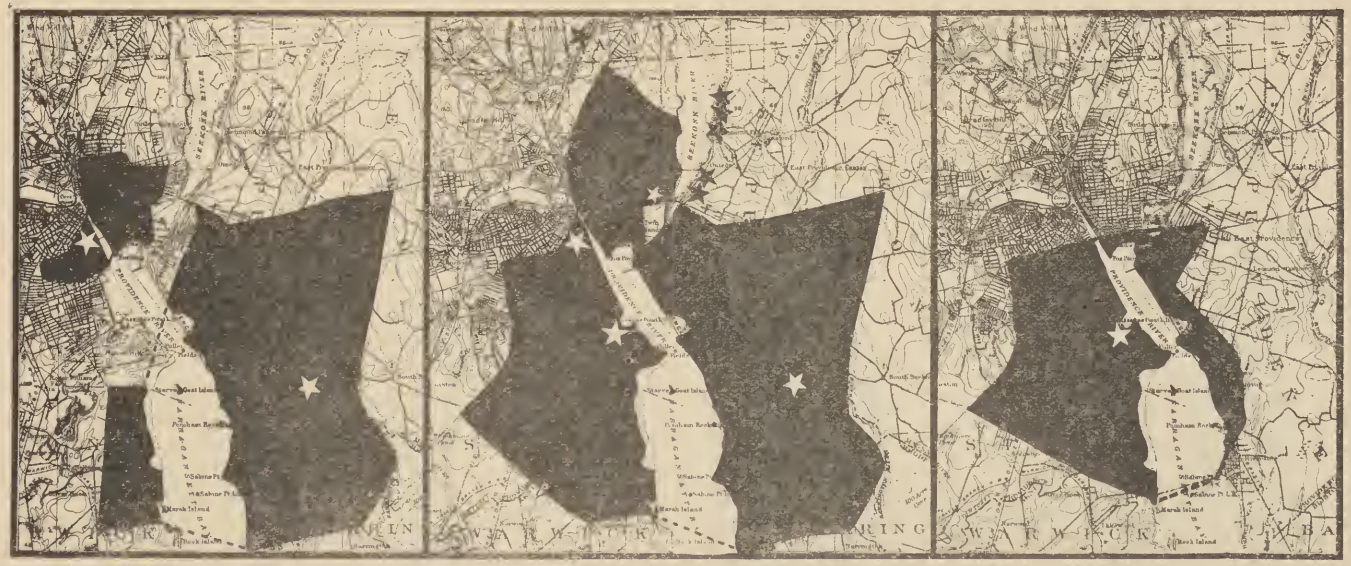
*All from down town section of Providence.

Total Area and Population Affected by Odors from Various Sources.

Theoretically, the area which may be affected by odors from any source is a circle whose radius is the travel distance of the odors from that source. On this basis the area which might be subject to the influence of odors from the Standard Oil Company refinery would cover 30.2 square miles and the area which might be subject to odors from the Texas Company plant would be 23.9 square miles, since odors from these two sources have been observed at distances of 4.8 miles and 3.8 miles respectively. The circles of influence of these two sources overlap considerably, and on the same theoretical assumption an area of about 13.4 square miles might be affected by odors from both sources.

Owing to the effect of prevailing winds, topographical conditions, and other factors, some of which are not clearly understood, odors usually travel farther in certain directions than they do in others. Our plotted map of the area known to be affected may, therefore, be irregular in shape, and a large proportion of the area may be found to lie on one side of the odor source. By plotting the locations at which odors have been noted by our observers at various times diagrams have been made showing the known area affected by each of the various odor sources recorded in our investigation and the extent of these various areas has been measured. In computing the extent of the affected areas water surfaces have been eliminated since in a study of this kind it is the land surfaces with which we are principally concerned. Copies of three odor maps showing the total area affected by odors from all sources and the areas affected by odors from each of the three principal sources are reproduced opposite page 30.

By superimposing the odor plots upon a map showing the census enumeration districts and proportioning the population of the outlying enumeration districts according to the relative area of each which lies within the limits of the odor plot we have also estimated the population in each of the various odor areas. By this method of computation it was necessary to



Area affected by odors from Standard Oil Co. (lower right) and from Narragansett Electric Lighting Co. (upper left).

Total Area affected by odors from all sources.

Area affected by odors from the Texas Co.

MAPS SHOWING AREAS IN PROVIDENCE AND VICINITY AFFECTED BY ODORS FROM VARIOUS SOURCES.

Odor areas in black. Principal odor sources designated by stars.

assume that the population of the outlying enumeration districts was evenly distributed which is, of course, not the fact in every case, but by eliminating those portions of the enumeration districts which were known to be uninhabited or very sparcely populated this error was reduced to a minimum. In a few selected localities the population estimated by this method was checked by a house count and the figures obtained by the two methods were found to be in reasonably close agreement.

The total known area affected by odors from all sources as determined by our investigation covers over 23 square miles and includes an estimated population of over 126,000. This area and population is divided as follows:—

	Area Square Miles	Population
Providence	6.5	103,200
Cranston	2.4	5,700
East Providence	8.3	16,200
Warwick	0.6	700
Barrington	1.4	100
Seekonk (Mass.)	3.9	500

The greatest observed travel distance of odors from the Texas Company plant was 3.8 miles. The area known to be affected by odors from this source as recorded by our observations at various times covers about 8.0 square miles and included an estimated population of about 78,700. This area and population were divided as follows:—

	Area Square Miles	Population
Providence	3.9	65,500
Cranston	2.4	5,700
Warwick	0.2	200
East Providence	1.5	7,300

The area known to be affected by odors from the Standard Oil Company refinery comprises about 15.0 square miles with a population estimated at 21,300. The maximum observed travel distance of these odors was 4.8 miles. About 26 percent of the area and about 2 percent of the population subject to odors from this source lies in the state of Massachusetts. This area and population was divided as follows:—

	Area Square Miles	Population
East Providence	8.3	16,200
Cranston	0.8	3,900
Warwick	0.6	700
Barrington	1.4	100
Seekonk (Mass.)	3.9	500

The greatest recorded travel distance of odors from the power plant of the Narragansett Electric Lighting Company was 1.4 miles. The area affected by these odors covers about 1.5 square miles and includes a population of about 32,700. This area lies entirely within the city of Providence.

The determined area and estimated population affected by odors from various other sources, together with the observed travel distance, were as follows.—

	Travel Distance	Area Square Miles	Population
Tar Products Corporation	1.5	.84	6,800
*Slaughter House	1.9	.77	4,700
Standard Oil Co.—Red Bridge Station.	1.2	.46	3,200
Phillipsdale sources	1.5	.62	2,000
Colored Worsted Co	0.7	.25	1,850

*Exclusive of territory affected in Pawtucket not included in the investigation.

Area and Population Affected by Odors from Certain Sources on Specific Dates.

The total area and population under the influence of odors from the various sources, as plotted from the complete records of all odor surveys, have been discussed in the previous chapter. It is of course well understood that all territory subject to influence from any one source will not necessarily be affected at any one time.

A number of special surveys have been made by two or more observers working together in certain districts to determine the limits of the territory affected by odors at that particular time. In practically all of these special surveys an automobile was used for transportation, thus permitting a considerable territory to be covered quickly. The method employed in these surveys was to follow the odor in one direction as far as it could be detected and to record this point.

The car was then run some distance further, turned back toward the odor area, and the point at which odors could again be detected was recorded. After running well into the odor area and recording the odor intensity at various points, another turn was made and the odor limit at another point was determined, this procedure being repeated until a sufficient number of points had been determined to permit the odor affected area to be plotted on the map. By running outside the odor area at intervals and then returning, the sense of smell of the various observers was revivified, and the car freed from odors, thus facilitating the determination of the limits of the odor affected area and the distance of odor travel. The results of these individual surveys furnish valuable information as to the spread of odors under the particular conditions of wind and weather which prevailed at the time. Following is a synopsis of a number of such special surveys. The wind velocities stated are from records of the U. S. Weather Bureau. Other observations are from our own records.

Providence-Cranston-Warwick District, June 13.

1:45—4:15 A. M. Weather fair. Wind North, shifting; velocity about 3 miles per hour. Odors from Texas Company plant affected territory from Calla Street in South Providence South to Winsdor Road in Edgewood and from Providence River West to points in Roger Williams Park. Observed odor travel distance 1.8 miles. Area affected about 1.2 square mile. Population affected about 8,500.

Providence-Cranston-Warwick District, June 25.

1:00-3:20 A. M. Weather fair. Wind variable, shifting from Northeast to North and Northwest; velocity about 9 miles per hour. Odor of illuminating gas affected territory from the Gas Works at Fields Point as far South as Massasoit Avenue in Edgewood and West to Eddy and Broad Streets. Observed odor travel distance 1.8 miles. Area affected by Gas Works' odor about 0.29 square miles. Estimated population affected about 1,800. Odor from the Texas Company plant affected the territory from New York Avenue South to points in Lakewood about one mile South of the Pawtuxet

River, and from Providence River West to points on Elmwood Avenue just West of Roger Williams Park. Observed travel distance of oil odor 2.4 miles. Area affected about 2.0 square miles. Population affected about 11,000.

Providence-Cranston-Warwick District, July 5.

12.00 midnight to 1:30 A. M. Weather fair. Wind shifting North to Northeast; velocity about 9 miles per hour. Odor of illuminating gas from Gas Works at Fields Point affected territory in South Providence from New York Avenue South to Alabama Avenue and from Providence River West to Eddy and Broad Streets. Observed odor travel distance about 0.6 miles. Area affected by Gas Works' odor about 0.29 square miles. Population affected about 1,800. Odors from the Texas Company plant were noted throughout the territory from Calla Street and New York Avenue in Washington Park South to Arnold Avenue in Edgewood and from the Providence River West to points in Roger Williams Park. Observed travel distance of these odors 1.25 miles. Area affected about .085 square miles. Population affected about 6,000.

Providence-Cranston-Warwick District, July 9-10.

10:30 P. M. to 1:00 A. M. Weather overcast with occasional light showers. Wind variable East to Northeast; velocity 4 to 6 miles per hour. Odors from Providence Gas Company plant observed in district extending from Ernest Street South to New York Avenue and from the Providence River to Allens Avenue. Observed travel distance of these odors about 0.4 miles. Area affected about 0.13 square miles. Population affected about 1,100. The characteristic burnt rubber odor from oil plants etc. was noted from Trinity Square on the North to Arnold Avenue on the South and as far West as the junction of Cranston Street and Bellevue Avenue. The major source of odors affecting this district at this time was the Texas Company plant. On the shore at the southerly part of the area affected in the Edgewood section, however, odors were observed coming across Narragansett Bay which, from the direction of the wind, undoubtedly came from the Standard Oil Refining plant in East Providence. As these two odors were

practically identical in character, it was impossible at this time to differentiate between the small area on the South which was affected by odors coming across the Bay and the larger area affected by odors from the Texas Company. The observed travel distance of odors from the Texas Co. plant was about 2.0 miles and the distance from the Standard Oil Co. refinery to the South end of the affected district was about 3.3 miles. The total area affected by these odors was about 3.0 square miles. Estimated population affected was about 45,700.

Providence-Cranston-Warwick District, July 11.

5:30 P. M. to 12:00 midnight. Weather overcast. Wind variable Northeast to East; velocity about 6 miles per hour. The characteristic burnt rubber and sulphide odors were observed from Calla and Ernest Streets in Washington Park South to the R. I. Yacht Club and Pawtuxet River and West through Roger Williams Park to Pontiac Avenue in Auburn. Strong odors were noted as coming from the Texas Company plant travelling West to Southwest. At a number of points on the shore in the southerly part of this area the characteristic odors were also noted coming across the Bay on the wind from the direction of the Standard Oil Company refinery. As the odors from these two sources are practically identical, it was impossible to distinguish between them. From the direction of the wind it is more probable that the odors in Auburn came from the Texas Company, although it is quite possible that they were a mixture of odors from the two sources. The air line distance from the junction of Park and Pontiac Avenues in Auburn where odors were recorded to the Texas Plant is about 2.3 miles and to the Standard Oil Company refinery is about 5.0 miles. The exact northwesterly and southerly limits of the territory affected by odors at this time was not determined. From the observations made, however, it is evident that this area extended well up into the Elmwood district and some distance down into Lakewood. The area known to be affected by these odors at this time covered about 3.00 square miles with a resident population of about 9,400.

Providence-Cranston-Warwick District, July 13.

12.00 midnight to 1:15 A. M. Weather cloudy with some fog. Winds variable Southeast; velocity about 3 miles per hour. Odors from the Texas Company observed in the territory extending from the Texas Company plant North to Point Street at Allens Avenue and to the junction of Broad and Summer Streets, West to points at Somerset and Pine Streets and Southwest to Thurbers Avenue at Burnside Street. Observed odor travel distance about 1.7 miles. Area affected about 0.8 square miles. Population affected about 19,500.

During this survey faint odors were observed on Narragansett Boulevard and Maryland Avenue from Arnold Avenue to New York Avenue which from their characteristics and from the direction of the wind probably came from the Standard Oil refinery in East Providence. The area affected by the odors from this source was not worked out.

Providence-Cranston-Warwick District, July 22-23.

11.30 P. M. to 1:00 A. M. Weather fair. Wind shifting Northeast to Southeast; velocity about 4 miles per hour. The charcteristic burnt rubber oil odor was observed from R. I. Yacht Club in Pawtuxet North to the intersection of Eddy Street and Potter Avenue in South Providence. The exact westerly limit of the odor area was not determined, but distinct odors were noted at Potter Avenue and Broad Street and at numerous points on Broad Street going South. Odors affecting the northerly part of this territory were traced to the Texas Company plant and as the wind was shifting at the time, odors in the southerly part may also have come from this source. At the R. I. Yacht Club and at a number of points on Narragansett Boulevard the characteristic odors appeared to be coming across the river on the wind from the direction of the Standard Oil Company refinery. It is impossible, therefore, to definitely assign the odors observed in Pawtuxet and Edgewood to either of these sources alone. Odors of illuminating gas were recorded in this survey on Maryland Avenue and Allens Avenue from California Avenue North to the Gas Company plant. Odors of ammonia were also noted in the immediate vicinity of the Clapp Ammonia plant,

but not in any residental section. The observed travel distance of odors from the Gas Works was about 0.6 miles and of odors from the Texas Company plant about 1.2 miles. Assuming odors noted on Narragansett Boulevard were from the Standard Oil Company their travel distance was about 3.5 miles. The total known area affected by odors as determined in this survey was about 1.3 square miles with an included population of about 9,500.

Providence-Cranston-Warwick District, Sept. 4-5.

10.30 P. M. to 12:15 A. M. Weather fair. Wind Northeast; velocity about 5 miles per hour. Odors from the Texas Company plant affected territory from Ernest and Eddy Streets in Washington Park South to points in Warwick on the Apponaug Road at Warwick Avenue and Elmwood Avenue, and West to the junction of Reservoir Avenue and Park Avenue in West Auburn. Maximum observed odor travel distance about 3.5 miles. Area affected 5.9 square miles. Population affected about 20,000.

East Providence District, July 6.

8:00 to 10:00 P. M. Weather fair. Wind variable South to Southwest; velocity about 7 miles per hour. Strong odors from the Standard Oil Company refinery were recorded on Hope Street and at various points on Taunton Avenue, and on Fall River Avenue in Seekonk, also on Waterman Avenue near the Massachusetts-Rhode Island line, on the Old Barrington Road North of the refinery and at a number of intermediate points in East Providence. A considerable portion of the affected territory was rural with few streets, and it was not feasible to define its limits exactly. From the recorded observations the area known to be affected by these odors was about 2.0 square miles. Estimated population affected was about 800. Maximum odor travel distance noted was about 4.1 miles.

East Providence District, August 12.

12:00 to 1:30 A. M. Weather cloudy. Wind South to Southwesterly; velocity 11 miles per hour. At Standard Oil Com-

pany refinery white fumes observed coming from stacks and travelling in heavy clouds in a Northeasterly direction. On the Northeast side of the Plant a strong odor similar to burning rubber and sulphides mixed with heavy oil was noted which extended East to the bridge over the Ruhlin River. On Fall River Avenue in Seekonk in direct odor range from the refinery a sharp acid odor similar to sulphur dioxide was observed from the Peck farm North to Luther's Corners. Observed odor travel distance was about 2.2 miles. The known area affected was about 1.6 square miles; largely rural. Population affected was about 300.

East Providence District, August 13.

3:00 to 4:00 A. M. Weather cloudy. Wind Northwest to West; velocity about 7 miles per hour. Heavy white fumes with strong odor of heavy oil and hydrogen sulphides coming from the Standard Oil Company refinery observed on Old Barrington Road South to its junction with the Providence main highway and along the latter in a westerly direction for about one-half mile. The observed travel distance was about 2.5 miles. The area affected was about 1.4 square miles. This territory is largely rural, the resident population being estimated at about 100.

East Providence District, August 14.

1:00 to 2:00 A. M. Heavy fog. Wind Southeast; velocity about 6 miles per hour. Odors of heavy oil and hydrogen sulphide recorded on Barrington Parkway near the property of the Mexican Petroleum Oil Company, on Waterman Avenue at Pawtucket Avenue, and at James Street and Waterman Avenue in Watchemoket. This order increasing in intensity was traced back to the Standard Oil Company refinery as its source. The observed odor travel distance was 3 miles. The known territory affected was about 2.4 square miles. The population affected was about 4,000.

East Providence District, August 19.

3:00 to 4:00 A. M. Weather fair. Wind Northwest; velocity about 15 miles per hour. On Fort Hill smoke coming from

the Narragansett Electric Lighting Company plant was observed to have a distinct odor resembling baked beans. Limits of this odor were not defined. The observed odor travel was about 1 mile.

A strong burnt rubber odor was observed in the territory from Boyden Heights to Vanity Fair. Smoke observed coming from the stacks of the Texas Company plant on the opposite side of the river and blowing into this territory was undoubtedly the cause of this odor. The territory affected by these odors was approximately 0.5 square miles. The population affected was probably about 500.

On the Southeast side of the Standard Oil Company refinery heavy fumes with a strong odor of heavy oil and sulphides were noted coming from the stacks at the westerly end of the plant. This odor was followed along the Old Barrington Road to its junction with the Providence main highway near 100 Acre Cove. The observed travel distance of these odors was about 2.5 miles. The area affected, largely rural, was about 1.4 square miles, containing a resident population of probably not over 100 persons.

Magnitude of Nuisance Caused by Odors.

The degree or magnitude of the nuisance caused by odors from any source is a function of four variables, the intensity of the odor, the frequency, the duration of time over which it lasts at each period, and the number of people who are exposed to its influence. No one will question the fact that an intense odor is more of a nuisance than a mild one. A faint disagreeable odor which persists over considerable periods of time or which is of frequent occurrence must be considered a greater nuisance than a strong odor which occurs only at long intervals, or which lasts only a few minutes at a time. Furthermore, an odor no matter how offensive it may be, is a nuisance only when there are people to smell it. A very strong disagreeable odor which can be smelled only by a small number of people must therefore be considered less of a nuisance than an odor of much less intensity which spreads out over a large and thickly populated territory.

If each of these variables could be expressed quantitively and the figures representing them be multiplied together, we would obtain a quantity which would give us more a representative idea of the magnitude of the nuisance caused by odors from different sources than could be obtained by simply comparing the various figures for each. In such a formula the frequency might be represented by the number of days the odor occurred in a year or some other stated period. As it is not always convenient to continue odor observations for any fixed period, it would probably be better to express the frequency by the ratio between the total days when odor occurred and the total days included in the period of observations. Duration might readily be represented by the average number of hours per day while the odor lasted. Population affected could be expressed in direct figures, but in order not to have too many figures in our final result it would probably be better to express population figures in thousands. For the other factor in our formulas, odor intensity, we have as yet no generally accepted unit of measurement. This might satisfactorily be expressed, however, as parts per million of hydrogen sulphide or some other substance found to be a common component of a number of different odors, or perhaps by a factor representing two or more such substances. We may express this combination of factors by the formula:—

$$M = \frac{D}{T} \times \frac{H}{T} \times \frac{P}{1000} \times I \text{ or } M = \frac{DHP\,I}{1000\,T^2}$$

in which M=magnitude of the nuisance, T=total days of observation period, D=number of days odor noted, H=total hours of odor, P=population affected and I=intensity of odor.

The records of our investigation furnish reasonably complete data on two of these four points. The daily reports of our special observers combined with the reports of volunteer observers enable us to determine the frequency of odors in each district and from individual sources. By plotting these odor observations on a map we have obtained the areas known to be affected by various odors at different times and have estimated the population affected. On the subject of duration of time while the various odors lasted we have no reliable

information. Our special observers were on duty only for a small fraction of the time each night. Volunteer observers have reported a number of times that odors lasted all night and in certain cases that the odors persisted continuously for 24 hours or more. In a few of the special surveys made records of several hours duration of odor have been obtained. The figures obtained from these sources, however, are too few or too indefinite to be used in a computation of nuisance magnitude. The need of accurate and detailed records of this kind was recognized throughout the investigation, but they could only be obtained by keeping trained observers on duty in each of the odor infected districts all the time.

As stated in another chapter, the method which we were forced to use for recording odor intensities, while of some value for making comparison between observations in different localities and at different times, was so crude that the results cannot be used as factors in any attempt to express the magnitude of the odor nuisance mathematically.

Since two of the four factors in our formula are missing, we are unable to express the full magnitude of the nuisance caused by the odors from the different sources covered in our investigation. We may, however, combine our data on frequency of odor with the population affected and thereby obtain factors representing in some degree the relative degree of nuisance caused by odors from the various sources. For this purpose we have employed a modified formula:—

$$N = \frac{PD}{100\ T}$$

N representing the degree of nuisance, P the population affected, D the number of days odor was noted, and T the total days on which observations were made.

For purposes of comparison the relative degree of nuisance caused by odors from various sources have been computed by this formula and are shown below, but since figures obtained in this manner are necessarily inaccurate and may be criticized as unfair, further discussion is omitted.

Source of Odor.	Degree of Nuisance
Texas Co	283.0
Narragansett Electric Lighting Co	83.1
Standard Oil Co	76.0
Tar Products Corporation	6.8
Providence Gas Co	5.0
Phillipsdale Power Plants	2.2
Slaughter House	1.8
Colored Worsted Co	1.3

Conditions Affecting Odor Travel.

There are many peculiarities about the travel of odors and we have much to learn about the effect of various conditions which may have considerable influence. If there is little or no wind, odors probably travel very slowly from their point of origin. On the other hand a strong wind appears to dissipate them and they cannot usually be detected at any material distance. Judging from our own results an odor nuisance is most likely to occur under a condition of what are generally known as light airs. Two-thirds of the odors recorded by our various observers were noted at times when the velocity of the wind according to the U. S. Weather Bureau records was betweeen 5 and 15 miles per hour. In only one instance was an odor observed when the wind velocity was over 25 miles per hour, and in only nine instances were odors observed when the wind velocity was above 20 miles an hour. In some instances odors travel high while at other times with apparently similar conditions they may travel low. In a number of instances odors from the Standard Oil Company refinery could not be detected on the East Providence side of the River, although they were quite offensive on the Edgewood side. In one instance we traced an odor from hilltop to hilltop for some distance, but were unable to detect it in the valleys between. In other cases we have observed an odor settle in what was apparently an air pocket and remain a source of offense for a considerable time after it had ceased to be produced at its source. This condition is most likely to be observed when there is a fog and very little wind. We have also frequently observed strong odors on the wind blowing up certain

streets while parallel streets only a block distant will be practically free from odors. These apparent freaks of odor travel can only be explained by attributing them to differences in air currents caused by relatively small variations in the topographical features. Variations of this kind, especially when they are of regular occurrence, may be responsible for wide differences of opinion between residents of certain localities as to whether an odor nuisance does or does not exist, and thereby add considerably to the difficulties of establishing the facts.

Special Studies of Oil Burning Plants, etc.

While we were unable to make a complete investigation of oil burning plants, special studies were made of a few plants about which complaint had been made or which had been observed to be causing odors in certain sections. In addition certain special observations have been made on the Tar Products Company and on the Industrial Chemical Company plants for similar reasons. It should be clearly understood that the results of these observations are reported here as illustrative of the conditions which may prevail at any other oil burning plant of similar size and character and not because these particular plants are the only offenders of this class.

Narragansett Electric Lighting Co.

A series of special observations were made on the plant of the Narragansett Electric Lighting Company for periods of one to two hours on 20 dates between July 18 and August 13. The observer was instructed to ascertain if smoke was being emitted from this plant, to follow that smoke to some point where its odor could be detected and to record character and intensity of odor and place or places where detected. On six of these evenings no odors from this plant were recorded. On 14 other evenings odors from this source were recorded at various places. As noted elsewhere, the character of odor from plants of this type varies with the concentration and also with the completeness of combustion. The character of the odors produced by smoke from this plant was recorded by our observer on different evenings as follows:—

Offensive sulphides, 2; Burnt rubber, 3;
Sweetish burnt, or caramel, 3; Sweetish, irritating, 2;
Sulphurous, 4.

After establishing that smoke from this source was odorous or irritating, a watch was kept on this plant at intervals during the period from August 15 to August 27 to determine approximately what proportion of the time the dense brownish fumes characteristic of incompletely burned oil would be emitted from the stacks. This plant has eight stacks and our observer kept an accurate record of smoke emitted from each while he was on duty. The observations covered a total of 40.5 hours on 12 days. On two of these days during intervals of 3 hours and 5.5 hours respectively, no dense smoke was noted. On two other dates during intervals of five and one-half hours and four hours, smoke issued from one stack only for four minutes and seven minutes respectively. On four other dates smoke was recorded issuing from two stacks for 9 minutes and 15 minutes respectively during two observations of one hour each, for 30 minutes during an observation of two and one-fourth hours, and for 55 minutes during an observation of three hours. On another date during three and one-half hours two chimneys smoked for three minutes, two others for twenty minutes, and still another for fifteen minutes.

On three dates our observer was in a position to smell the smoke from these stacks and reports a distinct to strong burnt rubber odor. On one of these three dates smoke was recorded from two stacks for one minute, from another stack for seventeen minutes and from still another stack for 36 minutes, a total smoke period of fifty-three minutes during three hours observation. On the second date during six hours of observation one hour and thirty-five minutes of smoke was recorded, one stack smoking at intervals for a total of fifty minutes, a second stack for forty-eight minutes, and a third for one hour and fifteen minutes. During this observation two stacks smoked simultaneously for forty-eight minutes. On the third date during an observation of three hours, smoke was recorded from six of the eight stacks at one time or another, two stacks smoking simultaneously for a total time of thirty-seven minutes

and one stack smoking alone for an additional total of fifty-two minutes, or a total of one hour nineteen minutes smoke during a three hour period.

Colored Worsted Mill.

Special observations were made on the Colored Worsted Mill on fourteen different dates during July and August. At this time the mill was operating day and night, the power being shut off for a short period four times a day during lunch hour or for change of shifts. So far as our records show, good combustion was obtained at this plant at such times as the power load was on and the machinery was in operation. During the short periods when the power load was off, however, the dense brownish fumes, characteristic of incomplete combustion of fuel oil, and the characteristic burnt rubber odor, were observed to be discharged from the stack at this plant on numerous occasions. This smoke and usually the odor caused by it were recorded on three out of six morning observations, on five out of ten noon observations, on one out of five evening observations, and on two out of three observations made at midnight. The length of time this smoke was discharged varied from less than one minute to eleven minutes in different shut down intervals. The odor from this source was particularly disagreeable, and while the period of discharge was relatively short, under certain conditions the odor persisted over a considerable territory for some time afterward. In one instance odor from smoke discharged for four minutes during the noon period was distinctly noticeable for more than one-half hour in an area of about one-eight square miles extending from Pitman Street to Ticonderoga Avenue and from Butler Avenue to the Seekonk River. On another occasion the odor caused by fumes discharged from this source about 6:30 A. M. affected the same section until about 9:00 A. M.

Phillipsdale Plants.

At Phillipsdale are three oil burning power plants located in close proximity, two at the Sayles Finishing Plants, and one at the American Electrical Works, or Wire Works so called. Nearby is also located the Paper Mill of Bird & Son. Observa-

tions were made on these plants for periods of about two hours on nine different days between August 29 and September 10. A pinkish to yellowish white smoke was reported as discharged from the stacks at the Wire Works on seven of these days and a brownish smoke from the stack at the Glenlyon Plant of the Sayles Finishing Company on two dates. On four of these dates the smoke from the Wire Works was reported to have a distinct acid or sulphurous odor, with a burnt flavor at times. On two dates the wind was wrong and our observer was unable to get a record of the odor from this source. On one date the smoke from the two plants intermingled and while a distinct sulphurous and burnt odor was recorded in a considerable section on the East Side this odor could not be attributed solely to either of these sources. On another date a mixture of smoke from the Glenlyon Plant and the Paper Mill had a decided sulphurous odor which could not be definitely attributed to either source. During this series the observer failed to record the duration of time for the smoke observed or the odors noted, but stated later that smoke was emitted from these plants on the dates noted during the whole or greater part of the observation period.

Tar Products Corporation.

At this plant Tarvia and other road materials are manufactured from Waste Tar Products. Fuel oil is used as a source of heat and power. We have, therefore, two sources of odor, that from the oil burners and that from the manufacturing process. Special observations were made on this plant on ten different days and on three different nights between August 22 and September 10. A heavy smoke varying from copper color to rose color and to brown was reported from this source for one hour on each of the three nights and for a total of 27 hours 20 minutes on nine of the ten days the plant was under observation. On one night the odor of this smoke was described as, "burnt rubber," and on the other two nights as acid and irritating. During six of the nine day observations the wind was wrong and our observer was unable to get the odor. On the other three days during periods of one to three

hours a strong asphalt or "tarry" odor was reported from this source.

Industrial Chemical and Color Company.

This plant was reported to discharge dense yellowish brown fumes at times which were strongly acid and irritating. Special observations were made on this plant on nine days between August 29 and September 10, during a total observation period of thirty-four and one-half hours. Fumes of the character reported were observed to be discharged on five different days for periods varying from one to six hours. On three of these dates our observer recorded the wind as wrong to get odors, but on the other two dates faint acid odors were recorded for periods of one hour and thirty-five minutes and two hours respectively.

The Oil Burning Problem.

One of the significant features brought out by our investigation is the effect which the growing use of oil fuel may have upon the public health and comfort. From a mechanical viewpoint there is no question that oil is easier to handle, easier to store and more economical than coal as fuel. For this reason many new heat and power installations are being equipped to burn oil and numerous coal burning plants are being changed over to this type of fuel. The great bulk of fuel oil used in Rhode Island today is derived from Mexican Crudes which are high in sulphur content. Before these crudes can be safely used for fuel, the lighter boiling portions, i. e. the naptha and gasoline, must be removed, and in this process the larger part of the sulphur is left behind in the fuel oil. The average sulphur content of these fuel oils is about 4 percent and certain of them are stated to run as high as 6 percent or more at times. When this fuel is burned, if the combustion is complete, the sulphur is converted into sulphur dioxide or sulphur trioxide, both acid irritating gases which are discharged into the air from the top of the stacks. If the combustion is incomplete, part of the sulphur passes off as SO_2 and SO_3 and part as hydrogen sulphide or other sulphur compounds which mixed with the fumes of unburned or partly burned oil form a combination which is both irritating and malodorous.

In many instances oil burners have been installed in fire boxes which were designed for soft coal. In some cases the oil burners themselves are improperly designed or poorly installed. In addition we have the human element, the fireman or engineer who has learned to fire with coal, but will not or cannot learn that oil fuel must be handled differently. There is also the fireman who is late and rushes his fire by feeding his fuel too fast. All of these conditions are favorable to incomplete combustion which may cause any one of these oil burning plants to become a source of odor nuisance. The degree of nuisance which may be produced by plants of this kind necessarily depends somewhat upon the size of the plant or, what is the same thing, on the amount of oil consumed. A large plant improperly fired would undoubtedly be more offensive than a small one since it would cause a more intense pollution of the surrounding air. While individually the small plant may be relatively inoffensive, a number of small plants collectively are as likely to produce a serious nuisance as a large plant since the fuel consumption is usually watched more carefully in the case of the larger installations.

So far as we have been able to determine no one has attempted to collect complete statistics regarding oil burning installations in Rhode Island. From various sources, however, we have obtained a list of something like 170 such installations in the city of Providence, and data on the amount of oil used at a small number of these plants have been obtained. At 13 of the smaller plants the average oil consumption is about 5,400 barrels per year. At one large plant over 900,000 barrels of fuel oil are burned each year. It is evident, therefore, that a very conservative estimate would place the annual fuel requirement of oil burning installations located within the city limits of Providence at over 2,000,000 barrels. As previously noted, the East Side section of Providence has suffered severely during the past summer from fumes discharged in to the air by oil burning installations. Within easy odor travel distance of this section is one plant using over 900,000 gallons of oil per year and a number of smaller plants in which the aggregate oil consumption is considerably over 100,000 gallons.

For purposes of discussion let us asssume an annual consumption of one million barrels of oil. With an oil carrying 4 percent of sulphur, something like 30,000 pounds of sulphur would be burned every day in the year. If the combustion were absolutely complete and all sulphur were converted to sulphur dioxide, this would amount to 60,000 pounds of SO_2 gas discharged into the air each day. If approximately one-half the sulphur were converted to sulphur trioxide as we have reason to believe would be the case if excess air were used with the fuel, the stack gases discharged each day would carry with them some 30,000 pounds of SO_2 and 37,500 pounds SO_3, or the equivalent of about 19 tons sulphurous acid and 23 tons sulphuric acid per day. Under such conditions is it any wonder that residents of the East Side complain of throat irritation even when odors cannot be smelled.

One of the most famous cases of damage by sulphur fumes on record is that of the State of Georgia against the Tennessee Copper Company and the Ducktown Sulphur, Copper & Iron Company. Both these plants were located in Tennessee, the former about one-half mile and the latter about two and one-half miles from the state line. Sulphur fumes arising from the smelting of copper by these two companies were rapidly destroying valuable forests in Georgia from which the injured parties were unable to obtain relief by private litigation, when the state of Georgia finally took up the battle. As Georgia was a soverign state, the action was necessarily brought in the U. S. Supreme Court. In the case of the Tennessee Copper Co. an agreement was finally reached in which the defendant agreed to limit the smelting of ore from April to October to such an amount that all sulphur could be taken care of by a sulphuric acid plant. This agreement was recognized by the court and the case is continued indefinitely without a decree having been issued. In the case of the Ducktown Company the court finally issued a decree granting a partial injunction limiting the discharge of fumes during the growing season from April 10 to October 1, to 20 tons of sulphur per day, and to 40 tons per day during the remainder of the year.

The chief point of interest in this case is the fact that the Supreme Court of the United States has decided that in order

to prevent injury to growing forests located more than 2.5 miles distant, the amount of sulphur which may be burned daily must be limited to 40,000 pounds per day or only one-third more than the amount of sulphur contained in the fuel oil burned within a similar distance from the East Side section of Providence.

It would seem to the writer that the oil burning question is a problem which demands thorough, and careful investigation. In our investigation we have been able to make only a very brief and preliminary study of certain of these oil burning plants which have been complained of as causing offensive odors. There are other plants of the same kind which are also known to be sources of nuisance at times, and numerous similar plants about which we have no information, but which are each a potential source of nuisance. From all the evidence available it is believed that by careful operation complete combustion can be obtained at any properly designed oil burning plant and that there is, therefore, no good reason why such plants should be permitted to become a nuisance. The question of the control of sulphur oxides which result from complete combustion of these high sulphur oils is, however, a much bigger problem and one which may be of much more hygienic importance than the question of offensive odors. Before these problems can be solved with equal fairness to the manufacturer and power producer who use oil fuel and to the general public who must breath the air polluted by their products of combustion, a much more thorough investigation will have to be made, and in such an investigation, advice and assistance from experts on various phases of the question will be needed.

There is a growing feeling among leading oil men that the widespread use of petroleum as fuel may be an economic mistake when considered in its broad aspects. In a recent address before the Society of Chemical Industry in New York, Dr. William M. Burton, President of the Standard Oil Company of Indiana, summarized the future oil situatiom as follows:—

"The consumption of gasoline by internal combustion engines during the past decade has increased at a terrific rate. . . The increase in production of crude oil has not been

commensurate with the increased demand for its products. Naturally, one is inclined to speculate on what the future will be regarding an adequate supply of these important commodities. One suggestion would be that some of the large amounts of oil now being used for fuel and gas-making purposes be replaced with coal . . . the coal consumption in turn to be replaced in part by the further development of hydroelectric power."

We cannot, however rely on any movement for the conservation of the petroleum resources to bring an immediate solution of our problem. Fuel oil will continue to be used in increasing quantities for some years at least. For the best interests of our citizens and for the protection of the good name of our industrial communities we should attack this problem at once, and after a full and complete investigation should adopt such measures for relief as may be just and fair to all parties concerned.

The opinion has been voiced in certain quarters that even if a nuisance is being caused by oil burning plants, or by the storage and refining of petroleum, it is a necessary evil which is more than compensated for by the increased prosperity of the community. In a community which is dependent for its existence and prosperity upon a single industry a nuisance produced by that industry might be tolerated by common consent for some such reason. In a community like Providence, however, where there is a wide diversity of industry and which is also a business center for a considerable population, any one industry plays a relatively small part in the commercial prosperity of the entire group, and if that industry chances to be one which creates a public nuisance it detracts from rather than enchances the general prosperity of the community as a whole. As pointed out by W. H. Dittoe in his monograph, "How to Control Nuisances from Offensive Trades," the courts have held that:—

"It is no defense to an indictment for maintaining such a nuisance, that the business, trade, or occupation which occasions it is a useful one, or that it is really a public benefit, contributing largely to the enhancement of the wealth, prosperity or commercial importance of the community, or that it furnishes, on the whole, a convenience to the public which more than counterbalances the detriment it occasions. For if it is

in reality a nuisance or operates as such on the public, no measure of necessity, usefulness, or public benefit will afford a justification for maintaining it. Nor is it any defense to show that the business is carried on in the most prudent and careful manner possible; that the most approved appliances known to science have been adopted to prevent injury. The question of care is not an element in this class of wrongs; it is merely a question of results, and the fact that injurious results proceed from the business, under such circumstances, would have a tendency to show the business a nuisance *per se*, rather than to operate as an excuse or defense, and the Courts would feel compelled to say that, under such circumstances the business is intolerable, except when so far removed from residences and places of business as to be beyond the power of visiting its ill results on individuals or the public."

Injury to Property by Odor Nuisances.

That property may be damaged by odors or fumes from various industrial processes has long been recognized by the courts. Damage of this kind may result from actual injury to buildings, furniture, trees, or other vegetation, or it may result from the fact that the sale value of the property is affected through the locality becoming less desirable as a place of residence.

A few complaints have been made that material injury to property was being caused by odors in the area under investigation. In one case it was stated that silver would turn black over night at times when odors were strong and in one or two instances it was claimed that freshly painted buildings had been discolored by odors. It is well known that hydrogen sulphide or other sulphides will blacken silver. The ordinary tarnishing of household silverware is the result of the presence of small amounts of sulphides in the air or in the food with which the silver has come in contact. Lead paint will also be discolored by sulphides and for this reason ordinary white paint cannot be satisfactorily used around the laboratory, or in other places where any considerable amounts of hydrogen sulphide are used.

In view of the complaints it seemed advisable to ascertain if any appreciable amount of damage of this kind was being caused. All master painters doing business in Providence

East Providence and Cranston were therefore interviewed and asked to express their opinion and to cite any instances of the kind which had come to their notice. The replies of these various men were unanimously to the effect that in no case had they had any trouble in doing satisfactory work in the odor affected areas nor had any deterioration of painted surfaces come to their attention which could be attributed to the effect of the particular odors in question. In every case where complaint was made an investigation showed that the incident had happened at some indefinite time in the past, and at the time of the investigation there was no means of verifying the statement of the complainant.

Damage to property may also result through injury or destruction of trees and other vegetation by acid fumes. There is no question that large quantities of sulphur dioxide or sulphurous acid are discharged into the air from various sources of odor in the district covered by our investigation, and there is good evidence that fumes from these sources also contain sulphur trioxide or sulphuric acid in considerable amounts. Extensive damage to forests by fumes of this character has been mentioned in the celebrated Tennessee Copper case noted in another chapter. So far as has come to our knowledge no material damage of this kind has as yet been caused by acid fumes in Rhode Island, although no attempt has been made to search out possible damage of this character.

There is much evidence to support the belief that in certain sections at least property values are being affected by the frequent visitation of offensive odors. In a number of instances property owners have frankly stated that they or members of their families were being so seriously affected by odors that they would be forced to sell out and move elsewhere. In Edgewood and Washington Park more residential property was for sale during the past summer than any time for many years. Real estate dealers state that it is becoming more and more difficult to sell property in the odor affected sections at anything like a fair price. This, of course, means a direct financial loss to the property owner through reduced sale value or by reason of reduced rental value. The property owner in the odor affected section is not the only one to suffer however.

Every other member of the community will also be affected indirectly and will suffer some financial loss thereby.

The very considerable areas in Providence, Cranston, East Providence and Warwick which are most seriously affected by odors are almost entirely built up with homes of the better class, and a large part of the revenue of these cities and towns is derived from the taxes assessed upon this property. With any material general reduction in the taxable values in any section must come either in increase in tax valuation in other sections or a general increase in the tax rates. In either case the loss of revenue in one section must be made up by increased revenue from other sections. For this reason, if for no other, a serious odor nuisance of this kind should demand serious consideration from every taxpayer in the community irrespective of whether he owns property in the affected section or elsewhere.

Effect of Odors on Health.

The literature on the effect of odors on health is not particularly explicit. Some authors state that odors have little effect on health. This, however, is a question of the interpretation placed on the meaning of the words, "health," and "odors." An odor, considered purely in an olfactory sense as something which may be smelled, might not cause specific and lasting disease, although it might be offensive. Nevertheless, such an odor might produce a revulsion which would cause reflex actions of the digestive, nervous and muscular systems, giving rise to acute symptoms which, frequently repeated, might easily affect the general health tone and cause a lowered vitality and a reduced resistance to disease. Many substances which affect the sense of smell may also be direct poisons, or may cause irritation of the mucus or other exposed surfaces. In addition there are certain gaseous poisons such as carbon monoxide which have no smell. These would not ordinarily be called odors unless mixed with some other substance which could be smelled, although they might irritate the olfactory organs. The first class of reactions are sometimes classed as psychological, and the second as physiological. The line of demarcation between the physio-

logical and the psychological in such cases, however, is seldom clearly marked. As a matter of fact so called odors instead of being simple bodies are usually of more or less complex composition, that is, they are made up of a mixture of gases and of very finely divided solid or liquid particles in suspension, and the effect of the odor is a combination of the individual effects of its component parts.

The sense of smell varies as widely in different persons as does the sense of taste or any of the other senses. A concentration of odor which was very offensive to a certain number of persons might be only mildly disagreeable to the majority, and might pass entirely unnoticed by others. Yet these few persons might suffer severely if the visitation of this particular odor were frequent or long continued. Because such persons have a higher development of the olfactory sense is no reason why they should be compelled to suffer from a nuisance which is curable, or why they should be dubbed cranks or neurotics. Public health in its broad conception must include the few as well as the multitude, and our purpose is doubly served if in making life livable for the few we have also improved conditions for the many.

The growing interest in industrial hygiene and the study of health conditions attending different trades and industries has brought forth much valuable information on the poisonous effects of the fumes and gases which may be given off from a variety of materials under different conditions. This data on the effect of certain fumes etc. on the workers in different industries, if correctly interpreted, should also apply equally well to the effect of similar fumes or odors on the general population outside the works when such fumes are allowed to escape into the air. The degree of effect is merely a matter of concentration and dilution.

Unfortunately it was not feasible to make accurate measurement of the different components of the fumes or odors which have been prevalent in the different sections covered by our investigation. Knowing what these components may be and what symptoms they may produce when present in greater concentration, and also knowing what symptoms are exhibited by persons living in the odor infested districts, however, we

may reason from cause to effect and construct a chain of circumstantial evidence which will at least serve until more accurate data are available.

The probable or possible components of the various odors from the petroleum industry, from illuminating gas, from the distillation of tar, etc. have been discussed in another chapter.

In their elaborate treatise on the American Petroleum Industry, Bacon & Hamor devote an entire chapter to hygienic considerations. The physiological and symptomatic effect of a wide variety of different substances used or formed in the arts are described by Korber & Hanson and other writers on industrial hygiene. From these sources have been compiled the following resumé of the physiological effect of the various substances which are likely to escape into the air from processes such as those causing the odors noted in our investigation.

Inhalation of the volatile constituents of crude petroleum may produce symptoms affecting the central nervous system; they have, moreover, a markedly irritating effect on the mucus membrane of the respiratory organs. The hydrocarbons boiling at low temperatures act as nerve poison, whereas those boiling at higher temperatures produce a local irritant effect. The symptoms may be either acute or chronic. In very mild cases some workmen complain of vertigo, headache, nausea, bronchitis and mental depression, while others have a feeling of elation. Chronic poisoning causes vertigo, fullness and throbbing of the head, cough, dyspnea, anemia, general nervousness, hallucinations, and loss of memory. The effects vary with different persons. In cases of poisoning by inhalation of crude petroleum vapor, these symptoms may be complicated by intense inflammation of the mucus membrane of the respiratory organs, congestion, bronchitis, and inflammation of the lungs.

Benzine vapors cause headache, vertigo, nausea, vomiting, cough, irregular respiration, and cyanosis. 50 parts per million of benzine in air is decidedly poisonous, and 20 parts causes local symptoms. Poisoning from the vapors of benzine begins with headache, sickness, and giddiness resembling alcoholic intoxication. If much has been inhaled, the patient becomes unconscious with occasional muscular tremors,

convulsions, difficulty in breathing, and cyanosis. Under certain conditions pulmonic hemorrhages or necrotic and inflammatory changes in the lungs may be produced.

The still gases from refineries handling Gulf and Mexican petroleums contain sulphur compounds. There are instances on record of the death of animals from the inhalation of these gases and of the prevalence of "pink eye" among workmen exposed to their action.

Hydrogen sulphide may cause either acute or chronic poisoning: the symptoms of which are gastric distress, nausea, irritation of the conjunctiva, cough, headache, dizziness, general debility, vertigo, and digestive disturbances. 0.05 percent of H_2S produces irritation of the respiratory tract and 0.2 percent is fatal for animals.

Carbon disulphide vapors cause chronic poisoning: the symptoms of which are headache, giddiness, reduction of the reflexes, analgesia, acceleration of the heart action, nausea, vomiting, colic, and neuritis.

Sulphur dioxide produces irritation of the mucus membrane of the eyes, nose and throat. Continued action may produce bronchial catarrh, inflammation of the lungs and disturbances of digestion.

Sulphur trioxide vapors cause acute and chronic catarrh, inflammation of the lungs, loss of appetite, decalification of the bones and injury to the teeth.

Asphalt vapors cause mild inflammation of the conjunctiva in rabbits. Persons exposed to these vapors may acquire catarrhal conjunctivitis and bronchitis.

Vapors from boiling or distillation of tar may cause irritation or acne in various parts of the body, also loss of appetite, nausea, diarrhea, headache, vertigo, disturbances of the bladder, albuminuria and oedema.

Pyridine vapors act on the respiratory organs producing catarrh of the mucus membrane, hoarseness, irritation and choking sensation in the throat, headache, and vertigo.

Carbon Monoxide in very small amounts may produce chronic poisoning, the symptoms being headache, dizziness, nausea, palpitation of the heart, insomnia, general debility and reduction of the psychic functions. The amount of carbon

monoxide in the gases from the distillation of crude oils from different localities varies from 1.1 to 8.0 percent. Carbon monoxide is also present in considerable proportion in illuminating gas and may be present in certain amounts in the stack gases from oil and also coal burning plants under conditions of incomplete combustion.

Results of Health Inquiry Among Odor Complainants

While there is ample evidence that fumes of petroleum and similar products may produce illness and even death among workers exposed to them, in the great majority of cases which have been recorded the ill effects have been produced by considerable concentration of the fumes or vapors in question. In the odor affected districts included in our investigation, while at times the odors were very strong, the actual concentration of the vapors or fumes causing those odors was probably relatively small. One would not, therefore, expect to find acute poisoning among persons living in these districts. Certain of these fumes known to come from petroleum may cause chronic poisoning, however, and complaints had been made that many cases of illness were being caused by these odors. With the limited funds at our disposal it was out of the question to make a house to house canvass throughout the odor affected districts to ascertain what proportion of the resident population were being affected by the odors, and to determine the degree of illness among the persons who were so affected.

As it was clearly recognized that some accurate information along these lines was urgently needed, however, Dr. F. M. Evans, a physician well qualified by training and experience to undertake a study of this kind, was engaged to make a special inquiry among persons whose health was reported as being affected by these odors. Dr. Evans instructions were to spread out his investigation over the different odor affected districts; to obtain as many interviews as the limited time at his disposal would permit with persons who claimed to be made ill by odors; to obtain a complete record of symptoms and case history of such persons; and to report his own opinion on each case together with such other information as he might obtain which

might have any material bearing on the relation of odors to health. In the course of this investigation something like 300 persons, mostly complainants, scattered throughout the various odor affected districts were interviewed and 89 persons who had either been made ill in greater or less degree by odors, or who were ill of other diseases and whose symptoms were aggravated by such odors, were recorded. To the record obtained in this manner seven additional cases have been added from information obtained from other authentic sources.

In all, therefore, we have a record of symptoms and case history of 96 different persons who have been more or less seriously affected by these odors. The geographical distribution of these cases was as follows:— Providence-East Side section, 19 cases; Washington Park section, 38 cases; Cranston, Edgewood sections, 14 cases; East Providence, 4 cases; Seekonk, Luther's Corners, 21 cases. 16 of these 96 persons were ill with other diseases and there is little question that their illness was being aggravated by the effect of odors. Three of these were sufferers from asthma. 75 of these persons were female and 21 were male. It may be stated that our experience has been that women and children are more likely to be unfavorably affected by odors of these kinds than are men. The disproportionally large number of females in this list, however, may be partly attributed to the fact that Dr. Evans' visits were made during the daytime and he therefore interviewed a much larger proportion of women than of men.

The most common symptoms complained of were irritation of the throat, suffocation or choking sensation, nausea, headache, dizziness, and malaise. 24 of these persons claimed that the effect of the odors at times was so marked that it would wake them from sound sleep. The greater proportion of these persons exhibited two or more symptoms, only 19 persons giving a record of only one symptom. 46 persons gave a history of three or more symptoms and 14 persons gave a history of four or more symptoms. The record of the number of persons exhibiting the different symptoms is as follows:—

Symptom.	Number Persons
Irritation of Throat	42
Irritation of Nose	5
Irritation of Eyes	2
Suffocation	27
Choking sensation	13
Headache	44
Dizziness	22
Nausea	56
Gastric trouble	2
Malaise	25

In a considerable number of instances persons complained that they would be waked up by a suffocating or choking sensation. This would usually be followed by nausea. In a certain proportion of cases persons complained of dizziness so marked that they were unable to get out of bed at night to shut their windows. In a considerable proportion of cases also it was stated that nausea, headache, dizziness, and malaise persisted into the following day, after the odors causing the symptoms had ceased to be noticeable.

Results of Inquiry Among Physicians.

In order to supplement the data obtained by direct inquiry among complainants, early in November a questionaire was sent to all physicians in the state asking if they had had any patients who had been made ill by the odors under investigation and if they had had any patients ill with other diseases whose symptoms had been aggravated by such odors. The opinion of these physicians was also asked as to the effect of strong odors of petroleum, sulphides, and sulphur dioxide upon normal persons suffering from various diseases, and they were asked to express an opinion as to whether the fact that windows must be closed at night because of offensive odors would unfavorably affect the health of normal persons and of persons suffering from certain diseases. About 725 questionaires were sent out, and at the time this report was written 190 replies had been received.

A considerable number of physicians replied to certain of the questions, but stated that they did not feel qualified by

anything in their experience to answer other questions. A frank statement that a person does not feel qualified to answer a question is much more valuable for statistical purposes than would be an attempt to answer the question without proper knowledge of the subject. The failure of a considerable number of physicians to return answers to our questions was undoubtedly due to the fact that they had no experience on which to base a reply. The results of the replies by Rhode Island physicians to these various questions were as follows.

Question:— Have you had any patients who were made ill by odors alleged to come from oil refining plants.

Total number of replies	179
Number of physicians reporting that they have had such patients	10
Number of cases reported: men, 10; women, 18; children, 4; total	32

The symptoms reported as accompanying these cases were as follows:—

	Number of Cases	Number of Physicians Reporting
Nausea and Vomiting	6	2
Nausea and Malaise	6	1
Nausea, Suffocation and Sore Throat	3	1
Nausea, Headache and Insomnia	3	2
Nausea, Headache, Insomnia and Suffocation	1	1
Nausea, Headache and Loss of Appetite	1	1
Headache and Suffocation	2	1
Headache, Cyanosis, Pains in Chest and Abdomen	10	1

Question:— Have you had any cases of patients ill with other diseases whose symptoms have been aggravated by such odors.

Total number of replies	175
Number of physicians reporting that they have had such patients	9
Number of cases reported: men, 8; women, 4; children, 1; not specified, 2; total	15

The various diseases which physicians reported they know to have been aggravated by noxious odors and the number of physicians reporting such aggravation were as follows:—

Disease Aggravated.	Number of Physicians Reporting
Pulmonary tuberculosis	2
Other respiratory diseases	1
Asthma	2
Pharyngitis	2
Laryngitis	2
Anemia	1
Cardiac trouble	1
Nervous diseases	2

Question:— In your opinion would NORMAL persons be affected by strong odors of Petroleum, by Sulphide Odors, by Sulphur Dioxide Odors.

	Petroleum Odors	Sulphide Odors	SO_2 Odors
Number of replies	144	125	123
Number of physicians of opinion that normal persons would be affected by.	81	88	88

27 physicians were of the opinion that nausea and vomiting might be caused by petroleum odors; 22 were of the opinion that these symptoms might be caused by sulphide odors; and 18 that they might be caused by sulphur dioxide odors. 9 physicians were of the opinion that other stomach troubles might be caused by petroleum odors; 10 physicians that they might be caused by sulphide odors; and 12 that they might be caused by sulphur dioxide odors. 7 physicians were of the opinion that loss of appetite might be produced by petroleum odors; 5 believed that this effect might be caused by sulphide odors; and 3 that it might be caused by sulphur dioxide odors. 21 physicians stated that irritation of the nasal passages might be produced by petroleum odors; 27 physicians were of the opinion that such irritation would be caused by odors of sulphides; and 28 that it might be caused by sulphur dioxide odors. 6 physicians believed that irritation of the lungs might be produced by petroleum odors; 9 physicians stated that this effect might be produced by the odors of sulphides and 13 that they might be caused by odors of sulphur dioxide. 13 physicians were of the opinion that headache might be caused by petroleum odors; 15 that this symptom might be caused by sulphide odors; and 11 that it might be caused by sulphur

dioxide odors. 2 physicians stated that petroleum odors might cause dizziness. 6 physicians believed that the nervous system might be affected by both petroleum and sulphide odors and 7 physicians stated that sulphur dioxide odors might cause this effect. 4 physicians were of the opinion that loss of sleep might be produced by any of these three odors. 4 physicians believed that petroleum odors might affect the health by producing a lowered vitality and 3 physicians that the same affect might be produced by either sulphides or sulphur dioxide odors.

Question:— In your opinion would persons suffering from Asthma be unfavorably affected by Odors of Petroleum, by Sulphide Odors, by Sulphur Dioxide Odors.

	Petroleum Odors	Sulphide Odors	SO_2 Odors
Number of replies	141	132	131
Number of physicians of opinion that persons suffering from asthma would be unfavorably affected by	101	113	116

Question:— In your opinion would persons suffering from Respiratory Diseases be unfavorably affected by these odors.

	Petroleum Odors	Sulphide Odors	SO_2 Odors
Number of replies	138	131	128
Number of physicians of opinion that persons with respiratory diseases would be unfavorably affected by	96	108	111

Question:— In your opinion would persons suffering from Nervous Diseases be unfavorably affected by Odors of Petroleum or Sulphides.

	Petroleum Odors	Sulphide Odors
Number of replies	123	118
Number of physicians of opinion that persons suffering from nervous diseases would be unfavorably affected by	88	85

Through an error, requests for an opinion as to the effect of sulphur dioxide odors on nervous persons was omitted from this question, but judging from the tenor of other replies, it is fair to

assume that the concensus of opinion of physicians would be that such persons would be unfavorably affected.

Question:—In your opinion would persons suffering from other diseases be unfavorably affected by such odors. If so, what diseases.

This question was apparently too indefinite and was answered by only one-third of the physicians making reply. Approximately two-thirds of the physicians who did reply were of the opinion that persons ill with other diseases would be unfavorably affected by all of these odors. There was not, however, any general consensus of opinion as to what other diseases should be included, the tabulation of replies showing some 25 different diseases which one or more physicians felt might be aggravated by the odors in question.

Question:— In your opinion would the fact that windows must be closed at night because of offensive odors unfavorably affect the health of NORMAL persons, or of persons ill with NERVOUS DISEASES, ASTHMA, RESPIRATORY DISEASES, HEART DISEASE, or other DISEASES.

	Normal Persons	Nervous Diseases	Asthma	Respiratory Diseases	Heart Disease	Other Diseases
Number of replies	169	156	159	153	150	132
Number of physicians of opinion that such persons would be unfavorably affected	145	139	143	139	127	110

A significant feature of the replies to this question was the great preponderance of opinion among these physicians that clean fresh air during the hours of sleep is necessary, and that anything such as offensive odors which would lead people to keep their windows closed would be prejudicial to the general health. Only 7 physicians replied definitely that closed windows would not affect either normal or sick persons, while 33 different physicians stated just as definitely that persons ill with any disease would be unfavorably affected. Approxi-

mately 90 percent of the replies were to the effect that the symptoms of persons suffering from Asthma, Respiratory Diseases, or Nervous Diseases would be aggravated by sleeping with closed windows, and about 85 percent of these physicians were of the opinion that normal persons would be unfavorably affected by such procedure.

Conclusions on Effect of Odors on Health.

When our investigation was first started certain physicians and public health men with whom we discussed the matter expressed the opinion that the subject of offensive odors was not a health matter; that the effect, if any, was purely psychological. This is largely a question of the interpretation placed on the term health. With a very few exceptions the symptoms of the cases cited in the previous pages were temporary and not lasting. But, while the effect lasted, it was very real and in certain cases sufficiently severe to incapacitate the victim and of sufficient duration to interfere seriously with his regular avocation. In other words it reduced his mental and physical efficiency for a greater or less period of time at intervals which were dependent on the frequency of recurrence of the odors. It is well recognized by physiologists that intense and offensive odors may cause reflex actions affecting the nervous, digestive, and the secretory systems. Such reactions frequently repeated cannot help but have an unfavorable effect on the general health. Even if the effect is psychological rather than physiological, if the effects produced upon the system are the same, the ultimate effect on the health must be the same.

From the results of our own investigation we know that there are at least 96 persons who are or have been more or less seriously affected by these odors. From physicians have been received reports of 32 persons made ill and of 15 persons suffering from other diseases whose illness has been aggravated and perhaps their chance of recovery lessened from this cause. All or nearly all of these persons show a record of symptoms identical in character with those known to be caused by fumes or vapors of certain substances which from all available evidence are probable constituents of the odors which these persons have been forced to breath at least a material portion of the

time for a period of many months. The concensus of opinion among Rhode Island physicians, as expressed in their replies to our inquiry, is to the effect not only that the course of a number of diseases may be unfavorably affected by certain of the constituents of these odors, but also that the effect of these odors or fumes would be prejudicial to the continued good health of normal persons. To the weight of this evidence and opinion must be added the weight of opinion that the fact that windows must be closed at night because of offensive odors would in itself have an unfavorable effect on health even although the odors in themselves should not be capable of producing such an effect. But even if these data and opinions are not sufficient to establish this particular odor situation as a public health matter, the fact that these odors constitute a public nuisance which extends over a large area cannot be denied, and surely comfort and convenience of over 100,000 people who make their home in that area should be worthy of serious consideration.

Respectfully submitted,

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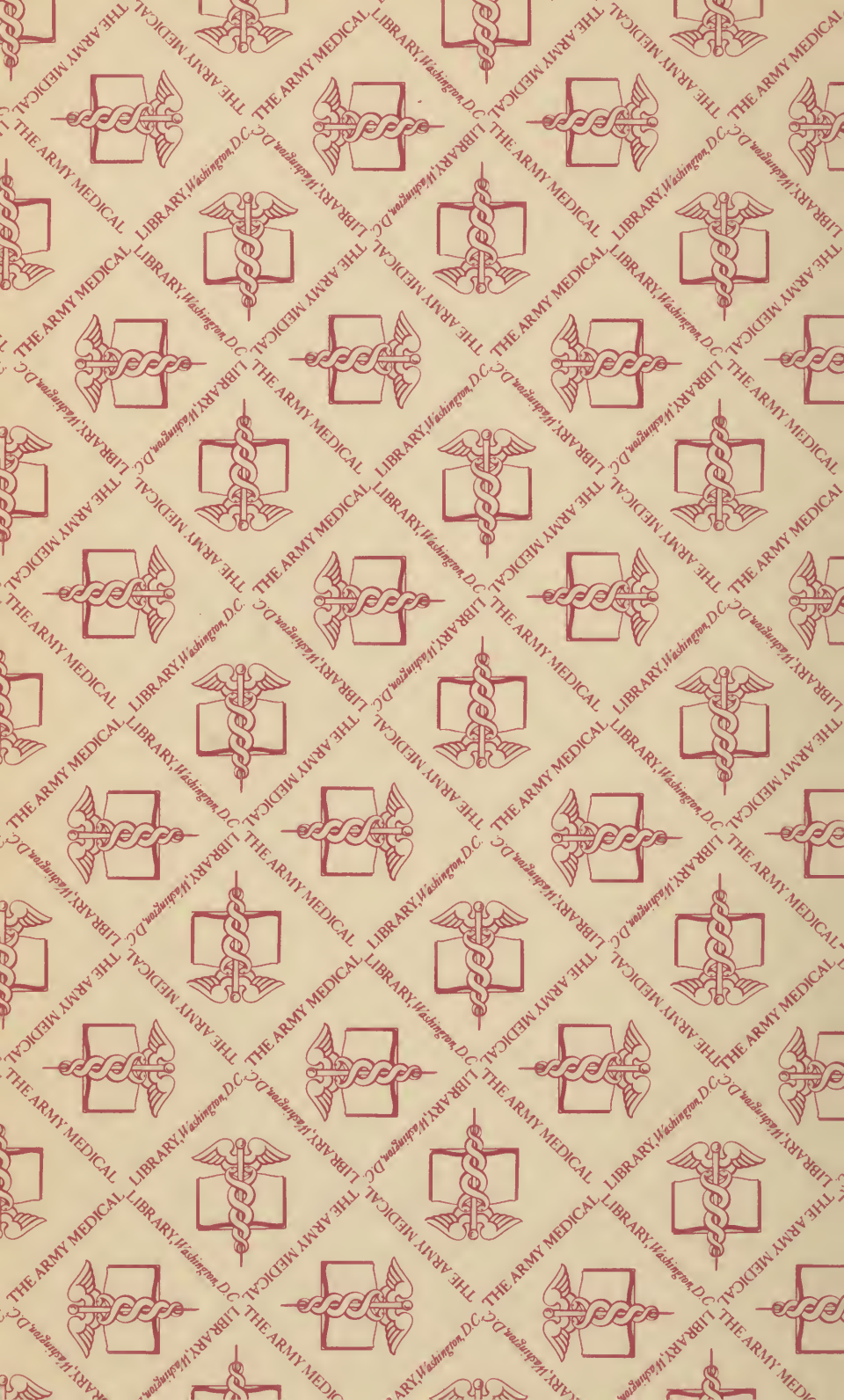
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